Physics at the future eRHIC

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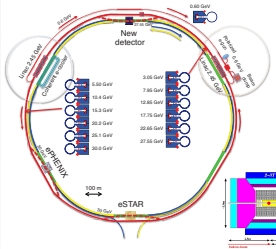
ABSTRACT

An Electron-Ion Collider facility (EIC) [1], a project although known as eRHIC, is under consideration at the Brookhaven National Laboratory (BNL). eRHIC is a machine designed to collide an electron beam with the currently existing RHIC hadron beam (protons and nuclei), capable of largely varying the center-of-mass energy produced in the collision and the polarization of both beams. The use of a high energy electron beam, the high luminosity of the machine expected in the order of 10^{34} events/cm² *s at the highest center-of-mass energy, and the new specifically designed detector, will make eRHIC the ideal "microscope" for investigating, with an unprecedented precision, the three-dimensional picture of the internal structure of the proton. Here I briefly review the most important topics of the broad physics case we aim to carry on at eRHIC and the large impact that such machine can have versus the current knowledge of quarks and gluons (the building blocks of the matter) and thus how they contribute to all the basic properties that characterize a single nucleon, such as mass, charge and spin.

eRHIC: an Electron-Ion Collider at Brookhaven Lab

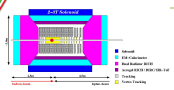


Beam energies:
- Polarized electrons: 5 to 20 GeV
- Polarized protons: 100 to 250 GeV
- Ions: 50 to 100 GeV/nucleon

✓ No other tunnel required: electron beam line will be added in the present RHIC tunnel (cheep and green)

✓ Up to 3 experimental locations along the ring

✓ Very high luminosity 10^{34} events/cm² *s (100 times higher than the previous electron-proton collider: HERA)



Newly designed dedicated detector
- Hermetic Central Tracking Detector
- Good EM calorimeter resolution with fine granularity
- Preshower electromagnetic calorimeter
- Very forward calorimeter and proton spectrometer

Physics motivation

➢ What is the space-time and momentum distribution of quarks and gluons in nucleons?

➢ What is the role of strong gluon fluids and parton saturation effects in scattering of nuclei?

➢ What is the polarization of gluons in the region where they are most abundant?

➢ What is the flavor decomposition of the polarized sea-quarks?

Physics goals

✓ Tomography of a nucleon/nucleus in three dimensions

✓ Understand the properties of gluons, which dominate the mass and density of the visible matter in the Universe!

✓ Determine quark and gluon contribution to the proton spin: solve the "spin puzzle"

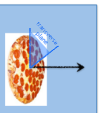
Imaging

Open questions:

⊙ In a fast moving nucleon the longitudinal size squeezes like a "pizza" but transverse size remains about 1 fm

⊙ Can we resolve transverse coordinate or momentum space in a parton density picture?

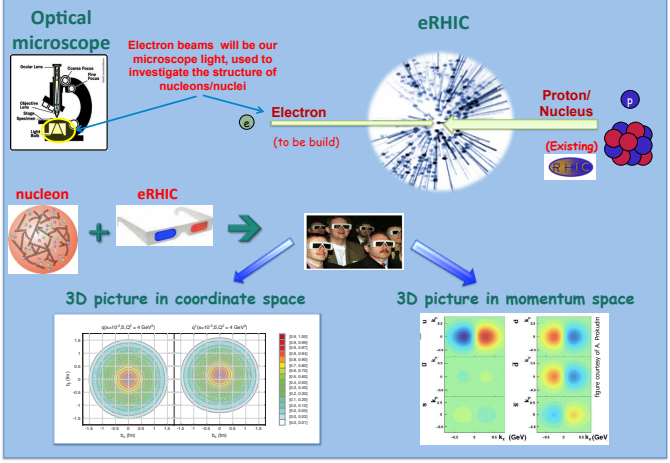
Goal: nucleon tomography!



Tomography is today commonly used in hospitals

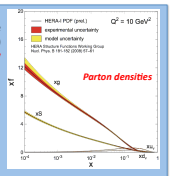
@ eRHIC we will do the same to nucleons and nuclei

The idea: building a large quantum "femto"-scope [2]...

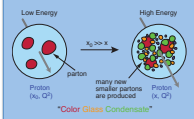


Saturation

Result from the HERA Collider: whilst the valence quarks dominate at large x values (~0.3) for $x < 10^{-1}$ the nucleon density is dominated by gluons

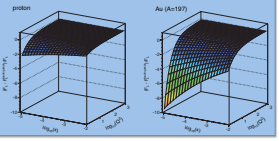


The x variable: known as "x of Bjorken" it is the fraction of the total momentum of the nucleon carried by the parton (quark or gluon) participating in the interaction



Gluon saturation: when gluon density becomes large enough, small gluons are believed to combine together as described in the Color Glass Condensate (CGC) theory [3], but this state of the matter to the present remains experimentally uninvestigated

Gluon saturation effects are expected to be higher in heavy nuclei ⇒ eRHIC will be an ideal to explore the saturation regime!



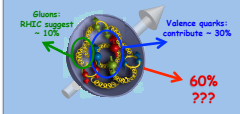
Access saturation: eRHIC will be sensible to saturation (e.g. in *e+Au* collisions) [1]. Figure shows the simulated measurement of the *longitudinal structure function* F_L for both protons and Au at eRHIC, saturation effects are much more prevalent in *e+Au [4].*

Spin physics

What is the spin:
In quantum mechanics, spin is the intrinsic angular momentum carried by a particle

Open question:
⊙ How quarks and gluons contribute to the spin of the proton?

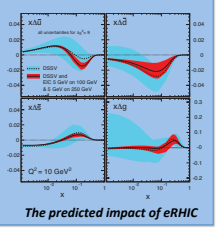
Goal: solve the "spin puzzle"



$\Delta g(x,Q^2) = g \to (x,Q^2) - g \to (x,Q^2)$

ONLY at eRHIC !

Unlike LHC, eRHIC will polarize both electron and proton/nuclei beams and will extend of 1000 times the currently available x-Bjorken range available at fixed target experiments [1], allowing to solve the puzzle!



The predicted impact of eRHIC

References:

[1] White Paper on the Electron Ion Collider – Available on-line:
http://skipper.physics.sunysb.edu/~abhay/eicwp12/draft/EIC-WhitePaper-11232012.pdf

[2] S. Fazio, T. Toll, and T. Burton – *"eRHIC: An Ultra-High-Resolution Electron Femtoscope"*
http://www.bnl.gov/rhic/inside/news.asp?a=2465&t=today

[3] E. Iancu, A. Leonidov, and L. D. McLerran, Phys. Lett. **B510, 133 (2001)**

[4] J. Bartels, K. Golec-Biernat, and L. Motyka, Phys. Rev. **D81, 054017 (2010)**

Acknowledgements

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